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Report No. G-2039-01

FISCAL YEAR 1992 PROGRAM REPORT

Robert C. Stiefel
Director

United States
Geological Survey

State Of Ohio
Water Resources Center
The Ohio State University

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The Ohio State University
Ohio

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U. S. Department of the Interior
Geological Survey

by

Ohio Water Resources Center
The Ohio State University
Columbus, Ohio 43210

Robert C. Stiefel, Director

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ABSTRACT

Most of Ohio's water problems are associated with water quality. Of primary concern are the sediments, nutrients and acids in the surface waters from urban, agricultural and mining areas, and the toxic and hazardous wastes that threaten the ground and surface waters. The focus of the 1992 State Water Research Program was directed at these areas. The research and technology transfer program consisted of the following activities: The technology transfer programs of the Water Resources Center continue to disseminate information about the water resources of Ohio to the local and state decision-makers, and provides technical assistance to help resolve some of the state's major water problems. One project was an oceanographic dynamics study, for Lake Erie, which used mathmatical models to calculate how contaminant loading from rivers will interact with the Great Lakes Forecasting System. This project will provide accurate and timely loading figures for the forecasting system. The hydrologics project by Steven G. Buchberger, studied alternate wastewater treatment and technologies using wetlands. The groundwater remediation project studied hydrophobic organic compounds (HOC) which are in groundwater systems and strongly sorbed by soil organic matter. This study characaterized the effects of chemical additives (co-solvents) in an effort to enhance HOC mobility in groundwater systems. The fate and transport project studied the dynamic features of pesticide-degrading microorganisms as they relate to changes in the redox speciation of their environment.

Training on these research projects was provided to eight students from four disciplines at two universities. These include five M.S. students in the areas of: Agronomy, Civil Engineering, Environmental Engineering (2), and Geological Sciences ; and one Ph.D. student in Geological Sciences(1). In addition, two undergraduate students, one in Agronomy and the other in Environmental Science gained practical knowledge and training by working on these projects.

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Water Problems and Issues of Ohio

Water is one of Ohio's most important natural resources. Bounded on the north by Lake Erie and on the south by the Ohio River and containing other extensive ground and surface waters, Ohio has an adequate supply of water to meet its immediate needs. However, the combination of large, heavily industrialized urban centers; extensive agricultural activities; high volume coal production and large coal reserves; and the associated demands for new energy production continues to cause concerns related to water quality and water management. In addition, extreme hydrologic events cause localized problems of both excessive water and water deficiencies at times.

Surface Water

The northern 25 percent of Ohio's area drains into Lake Erie, while the southern portion drains into the Ohio River. Runoff from Ohio's streams and rivers averages about 25 billion gallons per day. The state also receives nearly a billion gallons of runoff daily which drains through the Maumee River to Lake Erie from the neighboring state of Indiana; and Ohio has access to additional flows past its boundaries in Lake Erie and the Ohio River that total well over 150 billion gallons of water per day.

Last year, more than 16 billion gallons of water were withdrawn from Ohio's surface sources each day to meet the demands for municipal supplies; rural needs for domestic and livestock purposes; irrigation; and self-supplied industrial needs including cooling water for thermo-electric power generation. These demands account for only 60 percent of the available surface waters in the state's streams each day, and localized shortages only develop during certain dry seasons and periodic droughts.

The combined length of all the streams in Ohio approaches 44,000 miles, which means that there is approximately one mile of stream for each square mile of surface area in the state. In addition, there are more than 50,000 lakes, ponds and reservoirs within the state having a combined surface area of 200,000 acres. Only a small fraction of these, about 6,700 acres, occur naturally. The remainder are man-made impoundments that range in size from small farm ponds to large multipurpose reservoirs.

The reservoirs in the state are used to provide water for many different purposes including municipal, agricultural and industrial supplies; stream flow augmentation; flood control; and recreation. No impoundments in Ohio, other than those on the main stem of the Ohio River, provide water for downstream navigation or hydro-electric power generation. However, there is extensive navigation on both Lake Erie and the Ohio River, and consideration is being given to the installation of low-head hydro-electric generators at several developed dam sites throughout the state.

Flooding, still a major problem in Ohio, affects both urban and agricultural areas; and it has been estimated that nearly two million acres of land in Ohio are flood prone. This represents over seven percent of the total area of the state and includes nearly four percent of those areas classified as urban regions. Average annual flood damages in Ohio vary from year-to-year but amount to several millions of dollars annually.

Ground Water

Ground water is an important part of Ohio's water resources. Ground water underlies most of the state but is predominant in the glacial drift in the northwest, in the ice-contact and outwash deposits in river valleys along the border of the glaciated areas, and in the bedrock of the western portions of the state. Ground water supplies are largest in the glacial valley-train deposits in those drainage basins which border the Ohio River including the Ohio, Miami, Little Miami, Scioto, Hocking and Muskingum Rivers. Well yields from these deposits often exceed 500 gallons per minute (gpm), while aquifers in the glacial drift in the northwest and west-central parts of the state produce yields between 100 and 500 gpm. Isolated aquifers in the northeast, northwest and southwest have yields between 25 and 200 gpm, while much of the northeast contains aquifers whose yield is between 5 and 25 gpm. With the exception of the valleys along the major streams, most of the aquifers in the area that is tributary to the Ohio River have yields less than 5 gpm.

Three-quarters of Ohio's 650 public water supply systems use ground water as their source. In terms of volume withdrawn, however, a lesser share of these supplies comes from ground water, for only around a half billion gallons of ground water are withdrawn each day for public water supply purposes, while over one billion gallons come from surface water sources. However, ground water supplies nearly 80 percent of the rural water needs in Ohio, 32 percent of the irrigation waters and 21 percent of the industrial water demands. Nearly one billion gallons of ground water are withdrawn in the state each day to meet these needs.

Water Quality

It is the quality of water, rather than its quantity, that is the more critical and limiting condition associated with the use of both ground and surface waters in Ohio. The ground waters of the state frequently have relatively high, natural mineral contents; but, except for a few local areas, most of these waters are free from man-related contamination. Most complaints are related to increased levels of turbidity, bacterial populations and other substances from improperly sited or poorly constructed or maintained wells. Other problems are related to the spillage and leakage of brines and petroleum at oil wells in the southeastern part of the state; the mis-application of pesticides, herbicides and insecticides in agricultural areas; and the improper siting and operation of solid and liquid waste disposal facilities. Some minor ground water problems associated with the excessive use of highway de-icing salts or its improper storage have also been reported. The dissolved solids concentrations in Ohio's streams range between 120 and 2,500 milligrams per liter (mg/l). The higher concentrations are found in the Tuscarawas, Cuyahoga and Grand Rivers and in other stream reaches below major municipal and industrial outfalls or in areas subjected to diffuse source runoff.

Of the 23,000 miles of the principal rivers downstream of major urban areas in the state that have been monitored, 16,000 miles, or 70 per cent of these streams, meet the current water quality standards. Where problems do exist, they are frequently caused by inadequate municipal wastewater treatment at facilities that need be upgraded or expanded, or by combined sewer overflows.Substantial improvements in surface water quality have resulted from the development of pretreatment regulations for industrial waste discharges to municipal sewerage systems. Violations of the state's water quality standards occur most often in dissolved oxygen levels; ammonia nitrogen concentrations; the numbers of fecal coliforms; and the levels of heavy metals such as lead, zinc, and cadmium.

Acid mine drainage is a major cause of water quality problems throughout the Appalachian Coal Basin in the eastern United States. In Ohio this region extends in a band approximately 50 miles wide in a southwesterly direction from the east-central to the south-central parts of the state. Acid drainage from abandoned and improperly operated or reclaimed coal mined lands causes a loss of water for domestic and industrial uses; the degradation of water quality for recreational purposes; a lethal impact on the aquatic life in a stream; and an accelerated deterioration of highway and railroad bridges and electrical transmission lines and towers. Drainage from abandoned coal mines, both surface and underground, has impacted around 1,500 miles of streams in 27 counties in southeastern Ohio. Approximately 370,000 acres of abandoned strip mines, 7,000 acres of coal refuse piles and 3,000 underground mines are contributing to this problem. It has been estimated that four billion dollars would be needed to reclaim the abandoned mines and refuse piles throughout Ohio. Projected revenues from severance taxes earmarked for abandoned mine reclamation come to about ten million dollars annually. Obviously, the technologic problems and the economic costs associated with the control of acid mine drainage will continue to keep this a major problem of water quality in southeastern Ohio for years to come.

Little detailed information is available concerning the impacts that diffuse sources of pollution such as agricultural and urban stormwater drainage have on the quality of water in Ohio's inland streams. One concern with non-point pollution is the sediment that is dislodged from the land surface and carried to the streams. Of greater concern are the pollutants, such as the nutrients, heavy metals and toxic organic substances, that enter the streams attached to the sediments. No need for intensive, non-point source control programs to meet water quality standards in that area of the state that drains to the Ohio

River has been shown; but several studies are underway in the Lake Erie drainage basin to define the role of agricultural drainage on the water quality in the lake. Much more research and many more demonstration projects on the best management practices for agriculture, silviculture, mining and urban runoff control must be conducted before this problem is fully understood and control measures can be instituted.

The trophic status of several lakes and reservoirs has been studied; and the results suggest that the lakes and reservoirs in the sandstone bedrock areas of the state have generally lower trophic levels than those in the limestone bedrock areas or glaciated regions. Water quality was generally good to excellent in most of the lakes and reservoirs surveyed. However, excessive concentrations of copper and other heavy metals, bacteria and other pollutants normally associated with urban activities were identified in some of the lakes. Recent studies on Lake Erie indicate that there has been a reduction in several key pollutants and a gradual, but steady, improvement in the water quality in the Lake during the past few years. Phosphorus is a major pollutant which results in the excessive growth of algae and other aquatic plants. As these plants die and decay, they deplete the oxygen resources of the Lake. The construction of facilities to remove phosphorus at those municipal wastewater treatment plants which discharge directly to Lake Erie has been a major factor in the reduction of phosphorus loadings and of the subsequent reduction of the anoxic areas within the Lake. Additional work on the control of phosphorus from both diffuse sources and point sources needs be accomplished, but a significant start has been made.

Levels of bacteria have been reduced in the nearshore zones where municipal wastewater treatment facilities have been constructed. This has permitted regulatory agencies to re-open bathing beaches which were often closed during the period between 1960 and 1970. Concentrations of mercury and pesticides have been reduced substantially, principally because of the federal bans that have been instituted on their manufacture, use and disposal. PCB remains a major challenge, as does the control of sediment and the nutrients, fertilizers and organic chemicals that are attached to it.

Fish populations, including the walleye pike, are beginning to increase again in the lake; but the quality and diversity of fish is still far from what they were in the past. Thermal pollution is a localized problem in some near-shore areas. However, as closed cycle cooling is required on all power generation facilities, the extent of this problem will diminish.

PROGRAM GOALS AND PRIORITIES

The Water Resources Center at The Ohio State University encourages and supports research that is directed at providing information needed to solve the major water problems at the local, state, regional and national levels. The research program at the Center includes basic or fundamental research, problem oriented or applied research, and information dissemination and technology transfer activities.

During FY 1982, the Center, in cooperation with several groups of water-related agencies and officials throughout the State prepared a prioritized list of Ohio's major water resources problems. Based upon this analysis, the following ranking of these problems was developed:

1. **POLLUTION FROM DIFFUSE SOURCES** - including agricultural runoff; urban runoff; runoff from on-site waste disposal systems; runoff from active, reclaimed or abandoned coal and strip mines.

2. **CONTAMINATION OF DRINKING WATER SUPPLIES** - including surface and ground waters for both urban and rural uses by diffuse and point sources, and by the disposal of toxic and hazardous wastes on the land.

3. **TOXIC AND HAZARDOUS WASTE DISPOSAL** - including their control, treatment, disposal and impact upon land, water and air resources.

4. **POLLUTION FROM POINT SOURCES** - including municipal and industrial sources not yet in compliance with their NPDES permits.

5. **IMPACTS OF FLOODING AND DRAINAGE** - including flood damages, the use of flood plains and alternative structural and non-structural means of controlling floods and reducing flood damages.

6. **IMPACTS OF WATER RESOURCES DEVELOPMENTS** - including the impacts on various developments such as the extension of water mains and sewers into rural areas; flood control projects; hydro-electric power generation; water -based recreation; etc.

7. **INSTREAM FLOWS NEEDS** - including interrelationships among water quality, water quantity and land use practices on the instream flow needs for fish, wildlife, recreation and the optimum development and protection of these instream uses.

8. **IMPACT OF SYNTHETIC FUEL DEVELOPMENT** - including requirements for water and impacts of the disposal of wastes from these processes to water and onto the land.

9. **IMPACTS OF ATMOSPHERIC POLLUTION** - including a the effects of acid precipitation and atmospheric fallout on water quality and the environment.

10. **ALLOCATION OF WATER RESOURCES**- including the development of contingency plans for the allocation and conservation of limited waters supplies among competing water users during periods of low stream flows.

Subsequently, the Directors of the Water Resources Research Institutes in the Great Lakes, Upper Mississippi and Ohio River Basin's met to identify from their State problems the major water resources research priorities for the Region. A listing of these priorities is included at the end of this Section of this Report.

The focus of the 1992 State Water Resources Research Program was primarily directed at some of these critical needs. The research and technology transfer program consisted of the following activities: The technology transfer programs of the Water Resources Center continue to disseminate information about the water resources of Ohio to the local and state decision-makers, and provides technical assistance to help resolve some of the state's major water problems.

The project by Keith W. Bedford was an oceanographic dynamics study, using mathematical models to calculate how contaminant loading from rivers will interact with the Great Lakes Forecasting System. This project entitled "The Real -time Forecasting of Great Lakes Tributary Loads and Impacts Resulting from Storms and Other Extreme Events", will provide accurate and timely loading figures for the study.

The report by Steven G. Buchberger, "Simulation of Constructed Wetlands for Treating Wastewater" studied alternate wastewater treatment and technologies using wetlands. This hydrologic study of wetlands used mathematical models to describe and simulate transient variable water contaminant movement at constructed wetlands.

The groundwater remediation project by Franklin W. Schwartz, "Co-Solvent Processes in Aquifer Remediation" studied hydrophobic organic compounds (HOC) which are in groundwater systems and strongly sorbed by soil organic matter. This study characterized the effects of chemical additives (co-solvents) in an effort to enhance HOC mobility in groundwater systems.

The fate and transport project by Samuel J. Traina , "Effects of Redox-Induced Chemical Gradients on the Sorption-Biodegration of Pesticides at Colloid-Water Interfaces", studied the dynamic features of pesticide-degrading microorganisms as they relate to changes in the redox speciation of their environment. The specific objectives were to determine the effect of steady-state redox gradients on the sorption of selected pesticides to natural and model soils and sediments; to determine the effect of steady-state redox gradients on the biodegration of selected pesticides; and to determine the effect of steady-state redox gradients on sorption/desorption of selected pesticides as related to biodegradation processes.

The technology transfer program continued to work closely with the water professionals throughout the state and nation in cooperative efforts, jointly sponsored programs, newsletters and reports. Two new projects were added this year: Ohio Project WET,a water education program for grades K-12 was initiated; and a pilot project with the Department of Energy and seven other water resources research institutes on environmental management and restoration of DOE sites was started.

SYNOPSIS

Project Number: 02

Start: 7-1-91 (actual)
End: 6-30-93 (actual)

Title: The Real-Time Forecasting of Great Lakes Tributary Loads and Impacts Resulting From Storms and Other Extreme Events

Investigator: Bedford, Keith W., The Ohio State University, Columbus, Ohio

Focus Categories: CP,MOD,ST,WQL

Congressional District: Fifteenth

Descriptors: transports, forecasting, tributary loading, numerical modeling, Great Lakes

Problems and research objectives:

Nonpoint source watershed runoff from agricultural lands is especially aggravated during storms. With storms occurring roughly every seven to ten days in Ohio (Irish and Platzman~1962), the resulting delivery of these runoff pollutant products to the tributaries, and ultimately the Great Lakes (Erie), is a continuous series of sharp impulsive loads to the Lake. The storm driven loads often occur very quickly, coinciding with the maximum tributary discharges, while the post-storm recession is stretched over time as pollutants are slowly released back to the tributaries from flooded wetlands,etc. In determining the ultimate load to the Lake it is also necessary to account for the effects of strong stratification and water level fluctuations at the confluences (Lee and Bedford~1987b). The International Joint Commission (IJC) has designated over forty highly polluted Areas of Concern (AOC), some six of which are the major tributaries draining to Lake Erie. A consortium of the International Joint Commission, USEPA, Canadian Ministry of the Environment and USGS bureaus is charged with the responsibility of estimating these loads to the Great Lakes on a monthly basis. These agencies then in turn must use these data to implement water quality management decisions and remediation plans. The currently used operational load estimation procedure uses monthly average estimates based on empirically adjusted data collected quite far upstream at USGS monitoring sites. These sites are well upstream of the Lake confluence. The Maumee River gauge is over 30 km upstream. The data collected are so far upstream that all the AOC effects are ignored and one month averaging horizons effectively preclude resolution of the impulsive, spiky nature of the loading. In essence then accurate loading estimates are not available; the magnitudes are heavily misestimated and transformations within the downstream tributary/Lake mixing zone in the AOCs are unaccounted for. The result is poor long term water quality management.

In the case of non-conservative pollutants, such as fecal coliform bacteria, coastal trajectories of pollutant plumes are more important to water quality managers than monthly loadings. Combined sewer overflows lead to plumes of fecal coliform bacteria that present a hazard to coastal populations and cause a general degradation of the coastal environment. These plumes are short lived but dangerous. Locations of land fall and plume path can help in real-time release planning and in the long term planning for remediation. The Northeast Ohio Regional Sewer District (NEORSD) is responsible for remediating the persistent combined sewer overflows (CSO's) in the Cuyahoga River, the main tributary in the Cleveland area. In order to design the most cost effective system, NEORSD needs to know the effect of various water treatment scenarios on the water quality of Lake Erie and particularly the highly used recreational regions around Cleveland.

To account for plume trajectories in the coastal region an approach was devised and tested using the historical data base constructed by Great Lakes Forecasting System (GLFS)(Bedford~1993).

Methodology:

The vertical plane modeling technology has been adapted to the Maumee River (Podber~1991) and evaluated with known data on the interactions of flow reversals and stratification (Podber and Bedford~1992), as the first step in this two year project. Various combinations of the major factors affecting loading have been tested. These factors include tributary and receiving water temperatures, river transport and stage, lake oscillations and river basin bathymetry (silled and unsilled river bathymetry). The modeling strategy is predicated on the tributaries being relatively narrow and long which for Lake Erie is the case for all of the tributaries except Sandusky Bay (Bedford~1989). As noted in the 1989 article all these confluences exhibit significant interactions between vertical stratification and internal and surface, long period oscillations which impede Lakeward transport (Bedford and Mark~1988) and must be accounted for in the model.

Calculations of the horizontal and vertical velocity are made as well as calculations of temperature. A terrain following coordinate system is used which allows full resolution of bathymetry and channel geometry features. While this model is used to calculate a vertically resolved flow in the dredged channel portions, river stage and transport is calculated using the one-dimensional Dynamic Water Quality Model (Bedford et al.~1982) which is now the model in use for all such calculations by the US Army Corps. of Engineers.

To study the coastal processes, the 20 year database constructed by GLFS for NEORSD (Bedford et al.~1993) was used to drive a high resolution version (1~km) of the Great Lakes Forecasting System's hydrodynamic model. After study the 20 years of storms and Lake responses, two representative storms were chosen for analysis. River loads of fecal coliform bacteria were constructed to estimate different treatment and containment strategies. The domain for the model is 45 km of Lake Erie coastline that encompassed the region of concern for NEORSD. A one way nested grid approach is used to initialize and calculate a high resolution velocity and temperature field for the region.

Load estimates are provided to the nested grid model for the Cuyahoga River so that load trajectories can be calculated for the storm scenarios tested. The nested grid model provides a 1 km grid mesh with 12 layers in the vertical, thereby providing for a 3-dimensional water quality calculation. The pollutant plume is tracked for 96 hours until decay of the fecal coliform is almost complete. Impacted areas are clearly shown for the storms selected. Certain storms were selected after studying 20 years of data from a GLFS hindcast simulated Lake conditions data set. The NEORSD chose 2 worst case representative storms from which various scenarios were tested, including full unremediated release through various remediation strategies based on storm water control strategies. The river model used for the Cuyahoga was not the river model described above, the loading estimates were provided .

Principal Findings and Significance:

The major accomplishment to date is the construction and testing of the numerical model. Under a start-up grant (Grant PAS705-1) given by the Ohio Supercomputer Center, the numerical model briefly described above has been written and tested. The preliminary results have been published in a master's thesis and reported to the scientific community at a professional conference (see information transfer activities sheet). The significance of this accomplishment is that the questions concerning the accuracy of loading estimates can now be addressed. The creation and adaption of the numerical model for the Maumee River is essential for the accomplishment of the goals in this project. The fact that this code is viable and computer resources are available means that; 1) nowcasts can be performed, 2) integration into the Lake Erie Information Forecasting System (LEIFS) can be executed so that predictions of river stage can be made from the Maumee River and river inputs can be supplied to the LEIFS, 3) loading estimates can be computed from the numerical model for comparison with figures given to water quality management agencies.

The range of test cases that has been examined are for silled and unsilled bathymetry, and spring and autumn temperature conditions. For each case a complete calculation was made that extended over several 14 hour seiche periods. A horizontal resolution of 250 meters combined with 20 vertical slices is used to create a fine level of detail in the calculation. The advantage of the detailed vertical resolution is an enhanced ability to define vertical density structure in the flow field. To parameterize the small scale mixing effect, the Mellor and Yamada level 2.5 closure scheme was employed in the vertical. The numerical code uses the bottom following or sigma coordinate system, which simplifies the application of boundary conditions and enhances model portability at the cost of increasing the complexity of the governing equations. To date, temperature is the variable used for scalar transport. The model could just as easily use any conservative tracer.

The river model shows a decreased in the transfer of water properties due to the silled bathymetry, as expected,and a heating trend is seen in the regions directly behind the sills. Heat transfer for the unsilled case seems to be enhanced by a thin layer of intrusive lake water that tends to under ride the general oscillatory flow and the more complete flushing of the unsilled region.

In the terrain following coordinate model community there has been a practice of excluding 9 terms of the horizontal eddy diffusion term due to the complexity of those terms. The reasoning to support that omission has been based on the higher order derivatives in those terms. We left all of the terms in the equations that the transformation called for and then examined the magnitude of each term independently and summed the effect of all of the terms. The result was that in general the omission of the terms was unjustified and in some cases the omitted terms swamped the retained term (Podber and Bedford~1993).

For the fine grid coastal trajectories of the Cleveland plume, we were able to provide NEORSD with surface concentrations maps of fecal coliform bacteria at 12, 24, 48, and 96 hours after the CSO for the storms that were deemed to be representative of worst case situations. These maps were based on the loading estimates given by differing remediation scenarios and provided a scientific basis for the costly activity of sewer system redesign that NEORSD is currently undertaking (Bedford et al. 1992). The coastal trajectory methodology and implementation provide the backbone for the future study of tributary effects on the Great Lakes.

Horizontal resolution is a critical need for making detailed coastal plume trajectories and it is not likely that the Lake Erie hydrodynamic model used in GLFS will run at the resolution required to define a coastal plume. Coastal features which affect trajectories are on the scale of 100 m, an order of magnitude smaller still than this study. This research has created the framework for nesting high resolution within a coarse lakewide grid, which can be used for future studies in Lake Erie and will be even more important as GLFS moves to larger lakes where the use of a 1 km grid is impossible.

Dissertations:

Podber, David Paul, 1991, "Modeling Great Lakes Tributary Flow and Transport," M.S. Thesis, Civil Engineering Department, The Ohio State University, Columbus Ohio, pp. 125

Conference Proceedings:

Podber, David P. and Keith W. Bedford, 1992, "Modeling Great Lakes Tributary Flow and Transport," International Association of Great Lakes Research Conference, Waterloo, Ontario.

Bedford, Keith W., Wai, O., Podber, D., Yen, C.C.,and Regenmorter, L."A conjunctive Analysis of Combined Sewer Overflows and Receiving Water Current Magnitude and Direction." Sixth International Conference on Urban Stormwater Drainage, Niagara, Ontario, Canada, September. 13-16, 1993. Ed. J. Marcalak.

Podber, David P. and Bedford, Keith W., 1993 ,"A Terrain Following Coordinate System Approach to Riverine Modeling", International Conference on Estuarine and Coastal Processes, American Society of Civil Engineers, Chicago, Ill. September 1993.

Podber, David P. and Bedford, Keith W. 1993, " Estuarine Approaches to Modeling Great Lakes Tributaries." 12th International Estuarine Research Federation Conference November 14-18, 1993, Hilton Head, South Carolina

SYNOPSIS

Project Number: 03 **Start:** 07/91 (actual)
End: 06/93 (actual)

Title: Hydrologic Simulation of Constructed Wetlands for Treating Wastewater.

Investigator: Buchberger, Steven G., University of Cincinnati, Cincinnati, Ohio

Focus Categories: HYDROL, MOD, ST, WQL, WL

Congressional District: First and Second

Descriptors: constructed wetlands, wastewater treatment, hydrologic fluxes, contaminant transport, precipitation, evapotranspiration, Monte Carlo simulation

Problem and Research Objectives:

Efforts to treat municipal wastewater have lead to a proliferation of concrete and steel facilities in the United States over the past 70 years. Escalating energy requirements and increasing labor costs have generated economic pressures to develop other more cost effective yet environmentally sound ways to control water pollution. The search for alternate treatment technologies has led to the rediscovery of *natural* wastewater treatment systems.

Natural systems achieve wastewater treatment by exploiting the physical, chemical and biological processes that ordinarily occur within a plant-soil-water matrix. In contrast to conventional concrete and steel treatment facilities which require continuous operation of energy intensive mechanical equipment, natural treatment systems are designed to minimize the need for artificial controls. In addition, there is another very important distinction between natural systems and conventional treatment facilities. Natural treatment systems interact strongly with the atmosphere. The performance of a natural treatment system is significantly affected by rainfall, evaporation and temperature. Because these hydrologic fluxes change over time, natural treatment systems do not operate as a steady-state process.

Use of natural wastewater treatment systems will increase in the future. Optimal design and operation of natural systems are hindered, however, by a lack of understanding regarding complex biological, chemical and physical processes that regulate natural systems and by a poor representation of dynamic hydrologic mechanisms affecting treatment performance. This has led to imprecise design and operating criteria which promote expedient and over-simplified solutions at the expense of efficient and cost effective natural wastewater treatment systems.

The objective of this research is to synthesize and test a mathematical model which describes and simulates transient, spatially variable water and contaminant movement at constructed wetlands. The emphasis is on developing an improved understanding of how key hydrologic processes (including evaporation, precipitation, infiltration, temperature) affect wetland performance. New insights gained from this study will be used to formulate a rational reliability-based approach for sizing constructed wetlands for treating wastewater.

Methodology:

Conceptual Approach: Wetland treatment capability changes continuously during the course of a year with highest efficiencies achieved during warm summer months. One way to exploit the seasonal performance of wetlands is to recycle effluent whenever discharge concentrations exceed regulatory standards. It is assumed, therefore, that the constructed wetlands can be represented as a lined, continuously stirred tank reactor (CSTR) followed by a lined, plug flow reactor (PFR) that recycles, if necessary, back to the CSTR. The PFR is the primary device for wastewater treatment. While some treatment will occur in the CSTR, its chief purpose is to equalize flow by storing incoming wastewater and collecting recycled effluent whenever the PFR is unable to achieve desired levels of treatment.

Design Objectives: The problem of wetlands design amounts to finding the minimum size of the CSTR and the PFR to assure that effluent concentrations comply with regulatory standards. A probabilistic standard will be adopted here. For instance, the standard might require that effluent BOD concentrations not exceed 10 mg/l at least 95% of the time.

Process Simulation: The wetlands simulation model requires simultaneous solution of the hydrodynamic equations (continuity and momentum) for water flow and the mass balance equations for dissolved constituents in a CSTR and a PFR. Since the treatment system is subject to nonstationary hydrologic fluxes (waste loading, evaporation, precipitation, energy), the solution involves Monte Carlo simulation imbedded in a numerical solution scheme. An hourly time step will be used to model wetland performance. Key steps include:

(1) Generate mass loadings into the CSTR.
(2) Specify hydraulic flow regime parameters and initial conditions.
(3) Simulate temperatures, evaporation and precipitation.
(4) Solve hydrodynamic equations for depth and the flow along the PFR.
(5) Use results from steps (2) and (3) to compute effluent concentrations along the PFR.

(6) Determine whether or not the final effluent concentration from the PFR meets the water quality standard; if a violation occurs and if the number of violations exceeds the permissible count, then recycle effluent back to the CSTR.
(7) Determine the new depth of wastewater and new concentrations in the CSTR.
(8) Repeat steps (2)-(7) to simulate several years of hourly wetland operation.
(9) Produce frequency distribution of concentrations in PFR and depths in CSTR.
(10) Estimate reliability-based size of CSTR from distribution of wastewater depths.

Design Optimization: Here the goal is to identify the least cost design that complies with effluent discharge standards from feasible CSTR-PFR combinations. This essentially amounts to running the Monte Carlo simulation enough times to identify a minimum point or region on the wetland cost (size) response surface.

Model Application: The design procedure will be applied to two case studies at existing constructed wetlands located in humid and arid regions of the United States.

Principal Findings and Significance:

This project represents the first attempt to formulate the design of a constructed wetland in terms of transient spatially variable stochastic hydrologic fluxes that affect system performance. Since constructed wetland cells tend to be long and narrow, the wetland system was visualized as a lined prismatic open channel that functions as a non-ideal plug flow reactor. The wetland was subjected to variable loadings of municipal wastewater and random fluxes of atmospheric moisture and energy (precipitation, evaporation and radiation). The St. Venant equations for gradually varied unsteady free surface flow were linked with the advective dispersive decay equation for mass transport. These coupled equations were solved in one dimension to provide flows and depth averaged concentrations at any point along the wetland treatment system. The solution strategy used an implicit finite difference method imbedded in a Monte Carlo simulation scheme coded into a new program called **HydroSim**.

Results from continuous simulation show that wetland treatment systems are remarkably robust. Treatment performance is relatively insensitive to the fluctuations in wastewater loading and to the occurrence of precipitation or evaporation. Long detention times (typically several days to a week) tended to smooth out the variability in the pollutant loading pattern. Precipitation events increased the rate of discharge, reduced detention time and diluted concentrations in the wetland water column. In contrast, evapotranspiration decreased the rate of discharge, increased retention time and concentrated substances in the water column. Although the wetland interacted strongly with these atmospheric moisture fluxes, precipitation and evaporation had relatively minor influence on the overall treatment performance of the wetland system. Further, both processes tended to compensate for the effects of the other. Temperature emerged as the dominant environmental factor in governing the performance of the wetland treatment system. This finding reflects the fact that reaction kinetics are highly sensitive to prevailing temperature and underscores the importance of properly accounting for the heat balance in future models of wetland treatment systems.

This work provides a more realistic description than is presently available of water and contaminant movement through natural treatment systems and has added to our understanding of how key hydrologic factors impact the performance and integrity of natural wastewater treatment systems. There remains, however, an urgent need to verify these findings with field data collected at operating wetland treatment systems.

(11) Special recognition awards received by applicant:

Progress on this Ohio WRC-USGS project was instrumental in receiving support for new but related projects from the following sponsors:

Sponsor: Ohio Environmental Protection Agency
Title: Constructed Wetlands for Wastewater Treatment
Dates: January 1993 to December 1994

Sponsor: National Science Foundation Young Investigator Award
Title: Modeling Complex Environmental Systems Subject to Random Forcing Fluxes
Dates: September 1992 to September 1997

(12) Notable achievements:

Developed and demonstrated the first version of a fortran source code, called **HydroSim**, to simulate and quantify how hydrologic fluxes affect long-term operation and viability of constructed wetlands for wastewater treatment. Current work intends to couple the hydrodynamic algorithms with more rigorous models to account for the heat balance and biogeochemical cycling at constructed wetlands. Our ultimate goal with **HydroSim** is to provide a tool which can help practitioners identify optimal configurations and operating strategies for cost effective natural treatment systems.

Incorporated project developments (including **HydroSim**) into a new dual-level course on Design of Natural Treatment Systems which was taught to 20 students (seniors and graduates) in engineering and science during the Spring 1993 quarter at UC. The class emphasized constructed wetlands for wastewater management. This course will be offered again in Spring 1994 and then on an alternating year basis.

Served on the steering committee which planned and coordinated an NSF faculty enhancement workshop on constructed wetlands for wastewater treatment. Presented findings from this project to 40 other faculty from around the US who attended the workshop. We have requested one more year of support from NSF in order to reconvene in 1994 for purposes of compiling an instructor's course manual and to sponsor in 1995 several specialty sessions at suitable national conference(s).

(12) Notable achievements (continued):

Work on this project has lead to the following presentations, proceeding and publications:

Authors:	Buchberger, S.G., S. Hemmady and G.B. Shaw
Title:	Modeling transport of water and contaminants through constructed wetlands
Date:	September 13-18, 1992 in Columbus, Ohio
Forum:	Poster at Intecol IV International Wetlands Conference

Authors:	Buchberger, S.G., S. Hemmady and G.B. Shaw
Title:	Optimal size of constructed wetlands for wastewater treatment
Date:	September 13-18, 1992 in Columbus, Ohio
Forum:	Presentation at Intecol IV International Wetlands Conference

Authors:	Buchberger, S.G., and G.B. Shaw
Title:	Hydrologic simulation of constructed wetlands
Date:	May 24-28, 1993 in Baltimore, Maryland
Forum:	Presentation at AGU 1993 Spring Meeting

Authors:	Shaw, G.B., and S.G. Buchberger
Title:	Point precipitation models to simulate water balance at a constructed wetland
Date:	July 21-23 in Park City, Utah
Forum:	Presentation at ASCE 1993 National Conference on Irrigation and Drainage

Authors:	Wang, X., and S.G. Buchberger
Title:	Finite element model for contaminant transport through constructed wetlands.
Date:	May 24-28, 1993 in Baltimore, Maryland
Forum:	Presentation at AGU 1993 Spring Meeting

Authors: Buchberger, S.G. and G.B. Shaw
Title: An approach toward rational design of constructed wetlands
Date: June 1993
Forum: manuscript submitted to **Journal of Ecological Engineering**

Authors: Buchberger, S.G. and G.B. Shaw
Title: Effect of climate on design of constructed wetlands
Date: hope to finish by December 1993
Forum: manuscript will be submitted to **ASCE Journal of Environmental Engineering**

(13) Training accomplishments:

Student: George Shaw
Level/Field: MS in Environmental Engineering
Thesis Title: Effects of climate on treatment performance of constructed wetlands.
Status: MS receive June 1993

Student: Srikant Hemmady
Level/Field: MS in Environmental Engineering
Thesis Title: Efficient numerical schemes for constructed wetland simulation model.
Status: MS expected December 1993

Graduate work related to this project, but supported on by other sponsor(s):

Student: Ranjit Jadhav
Level/Field: MS in Environmental Engineering
Thesis Title: Hydrodynamic modeling of free water surface wetlands.
Status: MS expected December 1993

Student: David Siegert
Level/Field: MS in Environmental Engineering
Thesis Title: Optimal operation of constructed wetlands for wastewater treatment.
Status: MS expected June 1994

(14) Postgraduate employment:

George Shaw is now employed in the private sector with an environmental consulting firm based in Dayton, Ohio.

Srikant Hemmady intends to return to his native country (India) upon completion of his thesis.

Ranjit Jadhav intends to continue graduate study leading to a PhD.

David Siegert intends to seek employment in water resources/environmental engineering upon completion of his thesis.

SYNOPSIS

Project Number: 04

Start: 9/1/91 (actual)
End: 6/30/93 (actual)

Title: Co-Solvent Processes In Aquifer Remediation

Investigator: Schwartz, Franklin W. and Chin, Yu-Ping, The Ohio State University, Columbus, Ohio

Focus Categories: GW, HYDGEO, MET, SED

Congressional District: Fifteenth

Descriptors: groundwater, contaminant, remediation, column, solvent, displacement

Problem and Research Objectives:

In this study, we are characterizing the effects of co-solvents in an effort to enhance LNAPL mobility in groundwater systems. Predicting the effects of miscible solvents on sorption can be modeled using the following equation

$$\log K_{occs} = \log K_{ocw} - \alpha \sigma f_{cs} \qquad (1)$$

where K_{occs} and K_{ocw} are the organic carbon normalized partition coefficients of the binary solvent and water respectively, α is an empirical constant, σ is the solvency potential, and f_{cs} is the fraction of co-solvent in the aqueous phase (Rao et al., 1985; Fu and Luthy, 1986). Reliable values of σ are not well documented in the literature, and we report here a fast and precise reverse phase high performance liquid chromatography (RPHLC) method for determining σ.

Methodology:

RPHPLC retention times for individual compounds in co-solvent mixtures (for this study methanol/water) are measured using a C_{18} reverse phase column. The analyte capacity factor, k' (a normalized retention time) is used to determine the partitioning behavior of the analytes in the presence of co-solvents where k_w is the retention time of the

$$\log k' = \log k_w - \alpha \sigma f_{cs} \qquad (2)$$

compound in pure water. For RPHLC stationary interactions α is assumed to be one (Woodburn et al., 1986), although our data indicates a value for α of 1.1.

In RPHPLC column experiments, a mobile phase comprised of a precise methanol/water mixture was pumped through a C_{18} reverse phase column (NOVA-PAK) and into a detector (fluorescence or UV/VIS absorbance) that is specific to the analyte. Acetone was added to the sample matrix as an internal standard and measures the mobile phase retention time. We examined the elution behavior of 15 nonpolar contaminants using methanol concentrations that ranged from 65 to 90 percent by volume.

Soil batch equilibrium experiments are being conducted to verify RPHPLC estimates of K_{occs} for three polycyclic aromatic hydrocarbons (2-methylnaphthalene, phenanthrene, and pyrene) using equation 1 and our RPHPLC derived σ values. Values for α were taken from the literature and vary from 0.500 (Fu and Luthy, 1986) to 0.921 (Karickhoff, 1984). Soil batch experiments consist of soil; buffered water solutions with varying amounts of methanol to determine the effects of co-solvents and μL spikes of target compounds in a 50 mL centrifuge tube. The soils were obtained from the Ohio MSEA site in Piketon, Ohio, and from Florida (University of Florida - P.S.C. Rao). These soils provide a wide range of f_{oc} values for both aquifer and soil systems. Every batch experiment is comprised of seven sample tubes containing soil and different concentrations of a compound; seven control tubes containing respective varying concentrations of the compound; and a blank containing soil and buffered water solution only. After the tubes are spiked with a contaminant, the tubes are wrapped in aluminum foil to prevent photodegradation and placed on a shaker at constant temperature until equilibrium is reached (~ 48 hours). The tubes then are centrifuged for 1 hour at 23°C and 2000 rpm (~1000 g) and assayed on a spectrofluorometer (SLM-Aminco SPF-500) to determine equilibrum concentrations.

Alcohols that are completely miscible in aqueous systems are chosen as co-solvents due to the efficiency of alcohols in reducing the partition coefficients of compounds. In an aquifer co-solvent flushing system, a series of floods containing water and a small percentage of alcohol could effectively remove contaminants down to target levels after only a few pore volumes. A series of water only floods would flush any remaining alcohol from the system. Residual alcohol (ppm-ppb) could be biodegraded quickly and easily.

Principal findings and significance:

RPHPLC column results indicate an excellent correlation between the capacity factor and the fraction percent of methanol. RPHPLC yielded σ values for the fifteen aromatic compounds under investigation are in good agreement with literature values determined by other methods.

Batch experiment results show a pronounced effect on the sorption of three polycyclic aromatic compounds (2-methylnaphtalene, phenanthrene, pyrene) by a silty soil in the presence of co-solvents. A four to five-fold increase in the solution phase concentration of our analytes was observed as the methanol concentration was increased from 0 percent to 30 percent by volume, and this was accurately predicted using the above model when the value of α was set at 0.5. Solvency potential values elucidated from batch studies to those determined by RPHPLC and other techniques.

Soil sorption rate experiments using phenanthrene in varying methanol/water solutions are currently being performed in order to determine the effect of co-solvents on sorption/desorption kinetics. Preliminary data show an increase in the sorption rate with increasing co-solvent compostion. Our results appear to corroborate observations made by Brusseau and co-workers (1991) for the sorption/desorption of HOCs in soil columns.

The results from this research will be submitted to appropriate scientific journals for publication. The published results will be beneficial to other researchers studying the effects of co-solvents; to environmental planners remediating groundwater systems contaminated with LNAPLS; and to researchers and modelers studying the characteristics of multicomponent contaminant spills/sources.

Publications:

Xu, Yuping,1993, , "Immobilization of Lead by Hydroxyapatite in Aqueous Solutions", Master's Dissertation, Geological Sciences Department, College of Mathmatical and Physical Sciences, The Ohio State University, Columbus, Ohio
Supporting Section 104 Project Number, G 2039-01.

Training:

One Master's Degree in Hydrology and one Ph. D. Degree Hydrology

Post graduate employment:

The student that earned the Master's Degree is employed in the private sector.

The Ph. D. student has not completed his graduate work and at this time is continuing as a student.

SYNOPSIS

Project Number: 05

Start: 07/91 (actual)
End: 06/93 (actual)

Title: Effect of Redox-Induced Chemical Gradients on the Sorption-Biodegradation of Pesticides at Colloid-Water Interfaces

Investigator: Traina, Samuel and Olli H. Tuovinen, The Ohio State University, Columbus, Ohio

Focus Categories: ST, WQL, NPP

Congressional Districts: Fifteenth

Descriptors: solute transport, surface-groundwater relationships, pesticides

Problem and Research Objective:

The contamination of the nation's surface and groundwater aquifers by pesticides represents a problem of regional and national significance. This problem calls for the development of accurate models which can predict the fate of these compounds in natural waters. Clearly, a complete and thorough understanding of the interactions between chemical and biological processes is required to predict the persistence of pesticides. The proposed work will seek to characterize the dynamic features of pesticide-degrading microorganisms as they relate to changes in the redox speciation of their environment. It is the interfacial natural environment, spanning from highly oxidized to increasingly reduced conditions, that usually is the setting for biological degradative processes. It is the biodegradation potential associated with microorganisms in this redox-controlled, dynamic natural environment and the effects of redox on linked sorption-biodegradation reactions that we propose to elucidate in this work. Natural aquatic environments are characterized by interfaces which commonly involve dynamic oxidation-reduction (redox) gradients concurrent with gradients in pH, dissolved oxygen, carbon dioxide, nitrate, sulfate, and numerous other aqueous species. These gradients occur in sediments and bottom layers of surface waters as well as in groundwater aquifers. Gradients with dynamic changes in redox species and microbial activities can also be found in subsurface cores. Microbiological processes in interfacial environments range from aerobic respiration (oxygen as the electron acceptor) to highly reducing activities involving ferric iron reduction, denitrification, sulfate reduction, and ultimately methane formation. At present, there is no information available to evaluate the microbiological degradation of pesticides under conditions that occur in interfacial redox gradients. Dissolved oxygen, availability of anaerobic electron acceptors, and the redox potential of the environment are the major features that regulate microbial activities in such environments. The aerobic degradation of many pesticides has been extensively documented in the literature.

Recent data on a few selected pesticides also demonstrate at least partial microbial degradation under highly reduced conditions as observed under methanogenesis, but it is not known how these limited data can be extrapolated to other ambient redox conditions. Neither is it fully understood how redox status affects pesticide sorption, yet it is now apparent that sorption strongly influences the biodegradation of pesticides. This present lack of fundamental information restricts the development of accurate, mechanistic models of the fate and transport of pesticides in surface and subsurface soils, sediments and natural waters. The proposed research will redress this problem by examining the effects of redox on the sorption and biodegradation of pesticides at colloid-water interfaces. The results will enable us to predict the pattern of pesticide degradation in dynamic, natural environments characterized by stratification phenomena (particularly redox) and a high degree of interaction at the level of microorganisms and particulate materials. Information from these studies will be useful in evaluating the persistence of pesticides especially in confined aquifers and in sediment-water interfacial layers. There are little previous experimental data on the fate of pesticides in interfacial redox-dominated environments. The results of this study will greatly facilitate future efforts in the development of kinetic models to predict the fate of agricultural chemicals in groundwater environments. Additionally, this information will be useful in evaluating the complexity of factors that determine the fate of other xenobiotic compounds in confined environments. The specific research objectives are concerned with a series of laboratory experiments which will examine the effects of steady-state redox gradients on the coupled sorption and biodegradation of selected pesticides, simulating interfacial and subsurface environments.

1. To determine the effect of steady-state redox gradients on the sorption of selected pesticides to natural and model soils and sediments.

2. To determine the effect of steady-state redox gradients on the biodegradation of selected pesticides.

3. To determine the effect of steady-state redox gradients on sorption/desorption of selected pesticides as related to biodegradation processes.

Methodology:

Aquifer material (designated CT soil; courtesy of Stephen R. Hutchins, U.S. Environmental Protection Agency, Ada, OK) which degraded benzene, toluene, and xylene (BTX) compounds under denitrifying conditions was stored at 4°C until use in this study.

A microorganism (designated M91-3) capable of atrazine (2-chloro-4-ethylamino-6-isopropylamino-*s*-triazine) degradation was donated by Mark Radosevich (The Ohio State University, Columbus, OH). The organism was usually maintained anaerobically with glucose as the C source and atrazine as the sole N source. Anaerobic incubations were carried out at 25°C in the dark, and aerobic incubations were on a shaker table.

Flow-through systems containing soil and/or sediment were constructed of pyrex columns of length 340 mm and diameter 41 mm were fitted with rubber sleeve septa and tygon tubing and autoclaved before filling with soil. The medium was pumped in from the bottom through tygon tubing with a peristaltic pump, out through the top side port and into a container where it was stirred and allowed to recycle back through the column. The aerobic columns were open to air through a cotton-filled port protruding through a stopper fitted to the opening. The anaerobic columns were closed systems. Periodically, samples were withdrawn from the recycling container and analyzed for substrate disappearance with high performance liquid chromatography (HPLC).

A denitrifying benzoate-degrading microorganism was isolated in the course of the study. Aerobic growth was studied in liquid media containing benzoate, succinate, formate, glucose, acetate, or pyruvate added in 5 mM concentration. Growth with these substrates was also tested in the absence of oxygen. Uninoculated sterile media served as abiotic controls in all experiments. Growth was monitored by measuring the optical density at 660 nm. HPLC methodology was used to monitor the residual benzoate in culture solutions. Redox potential was measured with a Pt-electrode against an Ag/AgCl (4M KCl) reference electrode. The redox probe was calibrated with K-ferricyanide and K-ferrocyanide solutions.

Aerobic and anaerobic growth of this organism was also tested with N medium containing 3-CB, 2,5-dichlorobenzoate (2,5-DCB), 4-chlorobenzoate (4-CB), or 2,4-dichlorophenol (2,4-DCP). Cell density and residual substrate concentration were monitored as evidence for growth. HPLC analysis was used for chlorobenzoates and UV analysis was used for 2,4-DCP. The ability of the benzoate degrader to grow with sulfate and ferrihydrite as electron acceptors was tested under anaerobic conditions.

Multiport pyrex columns were filled with 5 mm pyrex beads and fitted with rubber sleeve septa, tygon tubing, and a stopper. An air stream traveled from a cylinder into a needle valve regulator, out through a 0.2 μm in-line filter into a gas dispersion tube which was fitted into a flask of sterile ddH_2O before entering the column through one of the side ports. Prior to inoculation, all bead-filled columns and tubing apparatus were autoclaved (30 min, 121°C).

In order to establish a microbial population (either atrazine- or benzoate-degrading) on the solid phase within the columns, 120 ml of media with 10 percent inocula were added to sterilized columns. The solid phase of a column was considered to be colonized when substrate disappearance occurred at a constant rate with subsequent additions of fresh medium. After one week of aerobic growth (during which fresh medium was added after substrate loss detected), the air inlet tube of each column was removed from the base of the column and attached to the top side port to allow anaerobic conditions to develop in the bottom of the column. Redox potential, nitrate loss, and substrate disappearance were each monitored, and the column was considered semi-anaerobic when denitrification activity was evident through nitrate disappearance. Anaerobic column experiments were initiated when microbial colonization of the columns was evident and conditions within the column were deemed semi-anaerobic.

Three different headspace conditions were employed in attempts to manipulate the redox of the system. First, aeration was introduced to the column through the second-from-top side port. Benzoate experiments with this system included (i) 5 mM each of benzoate and NO_3^-, and (ii) 5 mM benzoate with no alternate electron acceptor added. Another headspace condition allowed air entry through the top side port and N_2 entry through the base of the column. Benzoate experiments with this type of system included (i) 5 mM each of benzoate and NO_3^-, and (ii) 20 mM each of benzoate and NO_3^-. The third headspace condition used with these columns allowed air entry through the top side port. Benzoate experiments with this system included (i) 5 mM each of benzoate and NO_3^-, and (ii) 20 mM each of benzoate and NO_3^-.

Atrazine medium was used in columns colonized with the atrazine degrader. Two headspace conditions were employed. First, experiments with the air/N_2 system included (i) 0.1 mM atrazine medium with no alternate electron acceptor, and (ii) 0.1 mM atrazine + 5 mM NO_3^-. The second headspace condition allowed air entry through the top side port, with 0.1 mM atrazine and without an alternate electron acceptor in the column system.

Columns were also filled with ultra-pure sand as the solid phase for benzoate or atrazine experiments. Column conditions were static with no air or N_2 sources, but were sparged with N_2 while emptying and refilling with fresh medium. Sulfide was added as a reducing agent to the bottom zone of each column except for those used in aerobic experiments. Benzoate degradation experiments conducted with this system included medium variations of 5 mM benzoate and 15 mM NO_3^- with air sparged from the bottom port; 5 mM benzoate and 15 mM NO_3^- with sulfide added to each port and column headspace replaced with N_2; 5 mM benzoate and 15 mM NO_3^-; 5 mM benzoate, no alternate electron acceptor; and 18 mM benzoate and 54 mM NO_3^-. Atrazine experiments conducted within sand columns included medium variations of 0.1 mM atrazine and 5 mM NO_3^-, air sparged from the bottom; 0.1 mM atrazine and 5 mM NO_3^-, with sulfide added to each port; 0.1 mM atrazine and 5 mM NO_3^-; 0.1 mM atrazine, no alternate electron acceptor added; 0.1 mM atrazine, 5 mM NO_3^-, and 1.1 mM glucose; 0.1 mM atrazine and 1.1 mM glucose.

Substrate disappearance was monitored with HPLC and was quantified with external standards. The HPLC system consisted of a 5 µm C18 reverse-phase column (250 mm by 4.6 mm; Econosphere) equipped with a Spectroflow 400 pump, a Spectroflow 757 variable wavelength detector, an injector fitted with a 50 µl loop, and a Dionex 4270 integrator. A flow rate of 1.0 ml/min was used with the appropriate mobile phase. The detector was set at 280 nm for benzoate, 3-CB, 4-CB, and 2,5-DCB analysis. The isocratic mobile phase consisted of 20 acetonitrile:80 0.05 M sodium acetate buffer. Before the addition of acetonitrile, the pH of the sodium acetate buffer was adjusted to 4.5 with formic acid. Atrazine was analyzed with an isocratic mobile phase consisting of 65 methanol:35 water with the detector set at 220 nm. All samples and standards were diluted 1:1 with the appropriate mobile phase before analysis. Standards were prepared in the appropriate mobile phase.

Samples for UV analysis were centrifuged at 10,000·*g* for 15 min (4°C) and stored at 4°C until analysis with a Varian 2200 UV/VIS spectrophotometer.

Nitrate was analyzed with a HACH method or an automated Cd-reduction method. The HACH method involved sample pretreatment with bromine water and phenol water to remove existing nitrite. Nitrate was reduced to nitrite via Cd reduction of the sample. The sample was treated with sulfanilic acid and chromotropic acid (HACH NitraVer 3 reagent) to form a red-orange colored complex with chromotropic acid which was measured at 507 nm. An automated Cd-reduction method was used to analyze nitrate in samples from sand-filled columns. This colorimetric assay was conducted on a Lachat QuickChem auto analyzer. Samples obtained from glass bead columns were assayed for nitrite using a Hach assay. Nitrite analysis for samples obtained from sand-filled columns was conducted on a Lachat QuickChem auto analyzer.

Coulometry (a Haake Buchler chloridometer) was employed to measure chloride release from atrazine. The Bradford method was employed as a protein assay, with bovine serum albumin as external standards.

Principal Findings and Significance:

Anaerobic enrichments yielded an isolate (designated J92-6) which degraded benzoate completely under aerobic conditions with oxygen as the electron acceptor and anaerobically with nitrate as the electron acceptor. In the absence of external electron acceptors J92-6 did not degrade benzoate. An atrazine-degrading reference culture (designated M91-3) was able to utilize atrazine as sole carbon and nitrogen source under both aerobic as well as under anaerobic conditions without nitrate. M91-3 was also able to co-metabolize atrazine in the presence of glucose. Both cultures were used separately to inoculate the glass bead and sand columns described above.

Columns filled with glass beads were not effective in maintaining both aerobic and anaerobic conditions necessary to study the impact of a redox gradient on biodegradation. The data showed that the redox potential at different depths approached similar values within a few hours of the onset of each experiment, presumably as a result of diffusion and convection. The system was modified to minimize the mixing effect by filling columns with sand instead of glass beads. The use of sand seemed to allow the solution phase to maintain a gradient with respect to aerobic and anaerobic zones. In the absence of oxygen, the redox potential in the anaerobic portion of the columns could not be maintained at values below those measured in the oxic zone in the absence of a reducing agent. Sulfide was effective in maintaining a negative redox potential in the anaerobic portion of the columns.

Results of the redox gradient systems suggested that biodegradation was dependent on the growth requirements of native microbial populations rather than the redox potential of the system. Evidence for this finding is illustrated in Figure 1 which depicts the results of a column inoculated with the benzoate degrader J92-6. The column was aerobic at the top (8.5 cm depth), anaerobic in the middle (19 cm depth) and bottom (33 cm depth), and initially contained nitrate throughout the column. Sulfide was added to the bottom of the column to reduce the redox potential of that area. Benzoate degradation was coupled to aerobic respiration in the top and to denitrification in the middle and the bottom zones of the column. The middle and bottom zones of the column were anaerobic, but the bottom zone was amended with sulfide which abiotically reduced nitrate to nitrite at the outset. The nature of this abiotic reaction has yet to be determined. The nitrite thus formed was rapidly depleted and the residual benzoate was not further degraded until more nitrate was added. It was concluded that benzoate degradation by the strain J92-6 was dependent on the availability of a terminal electron acceptor, and was indirectly affected by the redox potential in terms of the sulfide reduction of available nitrate.

Columns which contained atrazine and were inoculated with M91-3 provided further evidence that biodegradation was not directly influenced by redox potential. Liquid culture experiments showed that M91-3 could utilize atrazine as the sole C and N source with or without external electron acceptors (O_2, NO_3^-). Atrazine was degraded throughout the column as illustrated in Figure 2 (top=8.5 cm depth, middle=19 cm depth, bottom 1=280 cm depth, and bottom = 33 cm depth) within each experimental redox gradient. Available nitrate was not utilized although the degradation rates at the different zones of the column were different. In anaerobic zones which did not receive sulfide amendment, atrazine was initally degraded faster than in the aerobic portion of the column. However, complete atrazine degradation occurred within the same time course in all zones that did not receive sulfide.

Table 1. Nitrate medium for benzoate and atrazine degrading bacteria.

Medium Designation	Mineral Salts and Trace Metals Solution (N medium) L^{-1}	Electron Donor
BN medium[a]	$(NH_4)_2SO_4$, 0.5 g K_2HPO_4, 0.5 g PIPES, 1.5 g $MgSO_4{\cdot}7H_2O$, 0.5 g trace metals solution, 10 ml	5 mM benzoate Electron acceptor: 5-15 mM NO_3^-
AN medium[b]	As in BN medium except $(NH_4)_2SO_4$ was omitted	0.1 mM atrazine

[a]The trace metals solution was prepared by dissolving 2 g nitrilotriacetic acid in 1 liter $dddH_2O$, adjusting pH to 6, then adding $CaSO_4$, 0.9 g; $MnSO_4{\cdot}H_2O$, 1 g; $Fe(NH_4)_2(SO_4)_2{\cdot}6H_2O$, 0.8 g; $CoSO_4{\cdot}7H_2O$, 0.23 g; $ZnSO_4{\cdot}7H_2O$, 0.2 g; $CuSO_4{\cdot}5H_2O$, 0.03 g; $NiCl_2{\cdot}6H_2O$, 0.02 g; $Na_2MoO_4{\cdot}2H_2O$, 0.02 g; Na_2SeO_4, 0.02 g; and Na_2WO_4, 0.02 g. The medium was prepared by dissolving benzoic acid, $(NH_4)_2SO_4$, K_2HPO_4, and PIPES in 970 ml of $dddH_2O$ and adjusting pH to 7.4 with NaOH before sparging with N_2 for at least 30 min and transferring 45-ml aliquots to degassed serum bottles which were then stoppered, crimp-sealed, and autoclaved (20 min, 121°C). Immediately before use, $MgSO_4{\cdot}7H_2O$, KNO_3, and trace metals were added via syringe from anaerobic sterile stock solutions. This medium was also used aerobically by transferring to a sterile 250-ml flask, inoculating, and incubating on a shake table.

[b]The medium was prepared by dissolving the atrazine, K_2HPO_4, and PIPES in 970 ml of dddH2O and adjusting pH to 7.4 with NaOH before boiling to remove oxygen and transferring 58-ml aliquots under N_2 to degassed serum bottles which were then stoppered, crimp-sealed, and autoclaved (20 min, 121°C). Immediately before use, $MgSO_4{\cdot}7H_2O$, KNO_3, and trace metals were added via syringe from anaerobic sterile stock solutions. Glucose (1.1 mM) was sometimes added from a sterile stock solution for co-metabolic growth.

Presentation to be Given as a Result of this Project:

Crawford, J.J., S.J. Traina, and O.H. Tuovinen. 1993. Microbiological Degradation of Arazine and Benzoate in Column Systems Containing Oxic and Anoxic Zones. Annual Meeting of the Soil Science Society of America, Cincinnati, OH, November 7-12, 1993.

Training:

Crawford, Jennifer J.,1993. "Microbiological Degradation of Benzonic Acid and Atrazine Within a Redox Gradient, 1993. Master's of Science Thesis in Environmental Science, College of Agriculture, The Ohio State University, Columbus, Ohio. (Jennifer will be a student at Ohio State through Fall Quarter 1993.)

Information Transfer Activities

The Water Resources Center is housed in the Agricultural Engineering Building on The Ohio State University campus. This location provides daily opportunities to work closely and share ideas with researchers in the College of Agriculture as well as the College of Engineering . It also provides a close working relationship with the OSU Agricultural Engineering Cooperative Extension Service. A series of tasks were continued or initiated to transfer and disseminate information developed by researchers affiliated with the Water Resources Center to a wide range of State, Federal, County and Municipal agencies; to the private sector, to the academic community and to private citizens throughout Ohio.

Water Luncheon Seminar

The Water Resources Center continued to co-sponsor bi-monthly Water Luncheon Seminar Programs for the water resources community in Central Ohio. These programs, are developed cooperatively with The Ohio Department of Natural Resources (ODNR), the Ohio Environmental Protection Agency (OEPA), the Soil Conservation Service (SCS), the District Office of the United States Geological Survey (USGS), and the Cooperative Extension Service of The Ohio State University. They continue to attract more than 350 water resources professionals annually from Federal, State, County and Municipal Agencies, the private sector and the academic community. These seminars provide a forum to discuss current state, federal and local water policy issues, problems, programs and research results. In addition to providing speakers for one meeting a year, the Water Resources Center provides the administrative and financial support for the seminars. The Center also provides technical equipment to assist the speakers with their presentations. The programs which were presented during the series follow.

Water Luncheon Seminar FY 1992

Date	Speaker/Agency	Topic
9/15/92	Gary Overmier Soil Conservation Service Columbus, Ohio	Looking Forward Through a Mirror, Reflections of Lake Erie Phosphorus Reductions From Agriculture 1982 - 2000
11/10/92	Valerie Orr Ohio Environmental Protection Agency Columbus, Ohio	Class 5 Injection Wells: What They Are and Their Potential for Contamination
1/12/93	Jim Raab Ohio Department of Natural Resources Columbus, Ohio	Study to Develop the Best Management Practices to Prevent Agricultural Chemical Contamination in a Karst Limestone Area of Ohio
3/9/93	Jim Morris Chief, Ohio Department of Natural Resources Columbus, Ohio	Ohio WET an Education Program for grades K-12
5/18/93	Terry Logan Professor Agronomy Department The Ohio State University Columbus, Ohio	"Current Issues in Beneficiary Use of Sludge at State and National Levels"

Other Conferences and Seminars the Water Resources Center Co-Sponsored or Supported in 1992

Date	Program/Co-Sponsors
9/13-17/92	**INTECOL IV** International Wetlands Conference, The Ohio State University, Columbus, Ohio
10/22-23/92	Water Management Association of Ohio's Annual Meeting, "Water Care, Conservation and Consumption", Columbus, Ohio
11/12/92	Wayne Nichols Memorial Seminar Program, "Trends in U. S. Water Law" by Dr. Earl Finbar Murphy, J. S. D. and "Ground Water Policy and Management in Ohio: Status and Needs" - Panel Presentation
5/4/93	Water Management Association of Ohio 1993 Spring Meeting: "Coordination and Finance of Water Resources Monitoring in Ohio", Mohician State Park, Loudenville, Ohio

Information Dissemination Activities

The Center continued meeting with the leading water resources officials in the state for the purposes of sharing information on current water management and policy issues; seeking continued support for our water research program and disseminating the information and technology developed through this program and others at the universities throughout the state and region.

The Center, continued publishing its quarterly newsletter "WATER" which focuses on Ohio's water research, technology, issues, legislation in process, education and Center activities. This publication has a wide circulation that includes public officials, water managers throughout Ohio, university researchers in Ohio and throughout the nation, as well as the general public. It has been well received. Mrs. Carol Moody, is the editor for the newsletter and the secretary to the Center.

Water Management Association of Ohio (WMAO)

The Water Resources Center continued to be the communications center for the WMAO. This not-for-profit, 300 member, state-wide organization promotes and supports the development, conservation, control, protection and utilization of the water resources of Ohio for all beneficial purposes. It is the only Ohio organization that is solely concerned with managing Ohio's water. The WRC provides staff support, office space and equipment to WMAO as a portion of the information transfer program.

Ohio Project WET

Discussions for this project began in the Fall of 1992 with the Ohio Department of Natural Resources, Division of Water and other Administrators. There was a strong interest in pursuing this project by the water professionals of Ohio and the Water Resources Center. Initial inquiries have indicated tremendous interest by classroom teachers for these materials. Coordination and support for the project now includes the Water Management of Ohio/Water Resources Foundation of Ohio, the Ohio Department of Natural Resources, Division of Water, the Ohio Environmental Protection Agency and the Water Resources Center. This project is housed at the Water Resources Center and is part of the information transfer program.

The Department of Energy Project

This is a collaborative, pilot project with seven water resources research institutes nationally. In Ohio, the Water Resources Center and the Ohio Technology Transfer Center are the lead agencies for this project. Ohio's role in this project, is to produce a database of all technologies currently used that could be adapted or applied to remediation of hazardous and nuclear waste sites, such as the Fernald plant in southwestern Ohio. Other locations will test the technologies at various sites, provide education programs on progress, and produce materials on the findings.

Ohio Water Atlas

The Center has continued discussions with the Ohio Department of Natural Resources, the Ohio Environmental Protection Agency, other state agencies and universities to develop a Water Atlas for Ohio.

Cooperative Arrangements

Program Development

A call for pre-proposals for the Fiscal Year 1991 State Water Resources Research Program was mailed to research administrators and qualified faculty investigators at more than 40 private and public colleges and universities throughout Ohio in mid-November, 1990. This announcement contained the research priorities identified for the major water problems in the Great Lakes, Upper Mississippi and Ohio River Basins by the Water Resources Research Institutes in the Region.

The announcement also required interested researchers to request a copy of the Preliminary Proposal Application Form which was to be completed and returned to the Water Resources Center in late January, 1991.

Pre-Proposals/Federal Guidelines

Preliminary Proposal Application Forms were requested by and sent to nineteen investigators and research administrators at eight colleges and universities in Ohio. One of these colleges responding was Central State University, an Historically Black University, although they did not submit a pre-proposal application for inclusion in the 1991 selection process. In addition to the application form, a list of the federal guidelines for the Program was also enclosed.

Evaluation/Selection Procedures

Eleven pre-proposals from five universities and colleges throughout the state were submitted for evaluation and consideration. The pre-proposals were subjected to a review by all of the members of the Water Resources Center's Advisory Committee. In addition, these pare-proposals were distributed to the various divisions within the four principal state and federal water-related agencies in the State by the representatives of these agencies who serve on the Advisory Committee, requesting that the divisions review the proposals. The four agencies included in this evaluation were the Ohio Department of Natural Resources, the Ohio Environmental Protection Agency, the District Office of the United States Geological Survey and the Agricultural Research Service in the United States Department of Agriculture.

The results of these reviews were presented at a meeting of the Advisory Committee where this panel selected seven of the pre-proposals and instructed the Center's Director to request fully developed proposals from the investigators for the Committee's further considered.

The seven selected pre-proposals were developed more fully and were re-submitted for consideration. The proposals were subjected to a technical review by at least three qualified evaluators selected by individual members of the Water Resources Center's Advisory Committee. many of these evaluators were from state and federal agencies or from the Battelle Memorial Institute.

The results of these reviews were presented at a meeting of the Advisory Committee and this panel ranked the leading proposals in the order they felt would best meet the needs and objectives of the Water Resources Center's program. The Advisory Committee then instructed the Center's Director to incorporate as many of these projects as Federal funds would permit into the FY 1991 Program, and to develop a project for information transfer for the Center. There was enough Federal monies to support five projects. Four of the slected projects were two-year projects and these four projects were funded for the FY 1992 Program.

The membership of the Water Resources Center's Advisory Committee, which includes representatives from five colleges and eleven departments of The Ohio State University and representatives of the three principal water-related state and federal agencies is included in this report.

Regional Cooperative Initiatives

The projects selected for this program were compared with the FY 1991 Program synopsis of the projects included in the programs of the other Water Resources Institutes in the Great Lakes, Upper Mississippi and Ohio River Basin to ensure that there was no duplication of efforts in the Region's research programs.

The Ohio State University has agreed to continue as a Charter Member of the Ohio River Basin Research and Education Consortium, and the Director of the Water Resources Center will continue to serve as one of the University's three representatives to the Consortium.

The Director has been appointed by the Governor of the State of Ohio to serve on the Ohio Water Advisory Council for the Department of Natural Resources, Division of Water. The Director has also been selected by the Governor of Ohio to be on the Blue Ribbon Task Force on Water Resources Planning and Development. The mission is to:"evaluate the organizational, technical, financial and planning infrastructure for water in the state and propose the actions taht are necessary to insure that the state's water resources are optimized, now and in the future, to promote economic development and recreation; protect public health and safety; and maintain and improve the environment. In 1992 he was appointed by the Mayor of the City of Columbus to the Columbus Environmental Science Advisory Committee.

Program Management

At least once each quarter, the Director contacts the Principal Investigator on each research and information transfer project to discuss progress made during the quarter and to discuss the next quarter's plan of activities. At this same meeting budget details are reviewed and discussed, and necessary operating and reporting procedures to the Water Resources's Center and to The Ohio State University Research Foundation's business office are described. Progress Reports or Completion Reports will be prepared for each Project by the Principal Investigators and will be used by the Program Director to prepare the Program Final Report.

All of the investigators are urged to publish the results of their findings in the technical literature of their major disciplines and in other journals that are appropriate to the topic of their research. They are also encouraged and invited to present their findings at the Water Luncheon Seminar that is a part of the technology transfer activities of the Center.

The manuscripts that constitute the project completion reports are first reviewed by the Director of the Water Resources Center. As needed, the Director seeks the advice and council of appropriate state, federal and university scientists for methods of enhancing the value of the technical completion reports to the water--related community in the state and in the region.

WATER RESOURCES CENTER ADVISORY COMMITTEE

COLLEGE OF ENGINEERING

1. Professor L-S Fan
   Chemical Engineering

2. Dr. Robert C. Stiefel
   Director, Water Resources Center

School of Architecture

3. Dr. Steven I. Gordon
   City and Regional Planning

4. Professor J. W. Simpson
   Landscape Architecture

College of Biological Sciences

5. Dr. Jeffrey Reutter
   Lake Erie Programs

6. Dr. David Culver
   Zoology

College of Mathematical and Physical Sciences

7. Dr. E. Scott Bair
   Geology

COLLEGE OF AGRICULTURE

School of Natural Resources

8. Dr. Robert L. Vertrees
   Resources Management

9. Ms. Theresa Heitzman
   Ohio State University
   Research Foundation

Ohio Environmental Protection Agency

10. Dr. John F. Estenik

Ohio Department of Natural Resources

11. James Morris, Chief
    Division of Water

United States Geological Survey

12. Steve Hindall
    District Chief

United States Department of Agriculture

13. Dr. Norman Fausey
    Agricultural Research Service

Publications

#	Type of Publication/Citation Information	Supporting Section 104 Project #
1.	**Articles in Refereed Scientific Journals**	
	Smith, S. C., C. C. Ainsworth, S. J. Traina, and R.J. Hicks.1992. Effects of Sorption on the Biodegradation of Quinoline. Soil Science Society of America Journal 56:737-747.	G-1607-02
	Traina, S. J. and B. M. Onken. 1991. Cosorption of Aromatic N-Heterogycles and Pyrene by Semectites in Aqueous Solutions. Journal of Contamination Hydrology, 7:237-259.	G-1607-02
	Buchberger, S. G. and G. B. Shaw, 1993, "An Approach Toward Rational Design of Constructed Wetlands", Journal of Ecological Engineering, (Submitted 6/93)	G-2039-01
	Fan, L-S, Leyva-Ramos, R., K. D. Wisecarver and B. J. Zehner, 1990. Diffusion of Phenol Through a Biofilm Grown on Activated Carbon Particles in a Draft Tube, Three-Phase Fluidized Bed Bioreactor, Biotechnology and Bioengineering	G-1607-02
	Tong, C. C. and L-S Fan, 1988. Multiplicity and Stability of a Three Phase Draft Tube Fluidized Bed Bioreactor for Phenol Degradation Involving Two Limiting Substrates, Biotechnology and Bioengineering, 31, 24-34.	G-1607-02
	Wisecarver, Weith D. , and L-S Fan.1989. Biological Phenol Degradation in a Gas-Liquid-Solid Fluidized Bed Reactor, Bioengineering, 33, 1029-1038.	G-1607-02
	Wisecarver, Weith D. and L-S Fan, 1989. Biological Phenol Degradation in a Gas-Liquid-Solid Fluidized Bed Reactor, Bioengineering, 33, 1029-1038.	G-1607-02
	Tang, W. T. and L-S Fan. 1987. Simultaneous Adsorption and Biodegradation of Organic Substrate Using Activated Carbon Particles with Immobilized Living Cells: Experiments Modeling and Simulation, AIChE Journal, 33 (2) 239-249.	G-1607-02
	Traina S. J. and B. P. Onken, 1991. Co-Adsorption of Pyrene and Aromatic Nitrogen Heterocycles by Hydrates Smectite, Journal of Contaminant Hydrology, 7:237-259.	G-1607-02
	Fan, L-S, R. Leyva-Ramos, K. D. Wisecarver and B.J. Zehner 1990. Diffusion of Phenol Through a Biofilm Grown on Activated Carbon Particles in a Draft Tube, Three Phase Fluidized Bed Bioreactor, Biotechnology and Bioengineering 35, 279-286.	G-1607-02

Tang, W. T. and L-S Fan 1989. Biological Phenol Degradation in a Gas-Liquid-Solid Fluidized Bed Reactor. Biotechnical and Bioengineering 33, 1029-1038. G-1607-02

2. Book Chapters

Fan, L. S. 1989. Gas-Liquid-Solid Fluidization Engineering, Butterworth Publications, 784 pages. G-1607-02

Fan , L-S., and K. Tsuchiya.1990. Bubble Wake in Liquid and Liquid Solid Suspension, Butterworth Publications, 363 pages. G-1607-01

3. Dissertations

Shaw, George, 1993, "Effects of Climate on Treatment Performance of Constructed Wetlands", MS Thesis, Environmental Science Department, University of Cincinnati, Cincinnati, OH G-2039-01

Hemmady, Srikant, 1993, "Efficient Numerical Schemes for Constructed Wetland Simulation Model, MS Thesis, Environmental Science Department, University of Cincinnati, Cincinnati, OH G-2039-01

Xu, Xuping, 1993, "Immobilization of Lead by Hydroxyaoatite in Aqueous Solutions", MS Thesis, Geological Sciences Department, College of Mathematics and Physical Sciences, The Ohio State University, Columbus, OH G-2039-01

Crawford, Jennifer J., Microbiological Degradation of Benzoic Acid and Atrazine Within a Redox Gradient, 1993,MS Thesis, Environmental Science, College of Agriculture, The Ohio State University, Columbus, OH G-2039-01

Spontak, D. N., 1990. "Effects of Cations on the Complexation of Polycyclic Aromatic Hydrocarbons by Dissolved Humic and Fluvic Acids, "MS Thesis", Agronomy Department, College of Agriculture, The Ohio State University, Columbus, Ohio G-1607-01

6. Other Publications

Nortz, Patrick E.,1991, An Allevial Aquifer Management Model at Piketon, Ohio, Agricultural Engineering Building, The Ohio State University, Columbus, Ohio G-1607-02

Fisher, S. W., 1991, Prediction of Surface Water Contamination by Pesticides, Ohio Water Resources Center. G-2039

Onken, N. M. & S. J. Traina. 1990. The Sorption of Non-Ionic Organic Solutes to Humic Acid-Clay Complexes. Agronomy Abstract pg. 235. G-2039

Kehrmeyer, S. R., and S. J. Traina. 1990. Bioavailability of Sorbed Napthalene to Pseudomonas Putida, Agronomy Abstract, page. 252. G-2039

O'Loughlin, E. J., S. R. Kehrmeyer, G. K. Sims. 1989. Isolation characterization and Substrate Utilization of Aquinoline Degrading Microorganism, Agronomy Abstract 81:224. G-2039

Buchberger, Steven G.,"Constructed Wetlands - Giving Mother Nature A Boost", UC Research, Volume 4, Number 1 Summer 1993, Pages 3-7, University of Cincinnati, Cincinnati, Ohio G-2039

Gordon, Steven I. and John W. Simpson, 1990. The Big Darby Creek Watershed Project Report to the Ohio Chapter, The Nature Conservancy , Columbus, Ohio, Department of City and Regional Planning and Department of Landscape Architecture, College of Engineering, The Ohio State University. (monograph) G-1607-01

Special Recognition Awards Received By Applicant

Fan, L-S	1993 Lumley Engineering Research Award Ohio State University/College of Engineering (to researchers honored for superior work)	G-1607-02
Fan, L-S	Fulbright-Hays Senior Scholar Award (to University of Cambridge, United Kingdom, 1990)	G-1607-02
Fan, L-S	Senior Visitng Scientist Award JSPS (Japan Society for the Promotion of Science). 1990	G-1607-02
Fan, L-S	Distinguished Visiting Professorship Award, National Natural Science Foundation of Peoples' Republic of China, 1991.	G-1607-02
Logan, T. J.	He is recognized by the U. S. Environmental Protection Agency (EPA) as a national expert in utilization of municipal sewage sludge on agricultural lands and was a consultant to EPA to in developing their 1979 sludge regulations. Since 1982 he has worked with USEPA helping develop their comprehensive sludge rules which become law in January 1992. He has also helped Ohio EPA develop their sludge regulations and chairs the advisory committee that determined sludge policy.	G-1607-01
Traina, S. J.	Young Investigator Award. 1990. Ohio Agricultural Research and Development Center (OARDC) (For scientists for their national and international contributions in basic research, developmental activities in the advancement of agricultural science and technology.	
Buchberger, S.G.	1992-93 National Young Investigator Award from National Science Foundation	

Notable Achievements:

Ward, A. and E. Scott Bair	Development of a Buried Valley Aquifer Management Model	G-1607/-02

The Ohio Management Systems Evaluation Area (MESA) Project was awarded to The Ohio State University Agricultural Engineering Department as a result of this initial project sponsored by the Water Resources Center. Various news articles on the Ohio MESA project are included in this report. Total dollars committed to MESA in 1989/90 were:

USDA-CSRS	$360,000/year for 5 years with potential for 5 year extension
USDA-ARS	$320,000/year for 5 years permanent allocation 10/1/93
USGS	$100,000/year for 3 years.

TRAINING ACCOMPLISHMENTS

The following tabulation shows, by fields of study and training levels indicated, the numbers of individuals participating in projects that were financed in part with this grant.

Training Category **Training Level**

Discipline	Bachelor's Degree	Master's Degree	Ph. D. Degree	Post Ph. D.	Total
College of Agriculture					
Agronomy	1	1			2
College of Engineering					
Civil		1			1
Environmental	1	2			3
College of Mathematics and Physical Sciences					
Geological Sciences		1	1		2
	2	5	1		8